Overseeding Common Bermudagrass with Cool-Season Annuals to Increase Yield and Nitrogen and Phosphorus Uptake in a Hay Field Fertilized with Swine Effluent

M. R. McLaughlin,* K. R. Sistani, T. E. Fairbrother, and D. E. Rowe

ABSTRACT

Haying common bermudagrass [*Cynodon dactylon* (L.) Pers.] is commonly used to manage field-applied manure P in the southeastern USA but is limited to summer. This 3-yr study was done to examine effects of extending the haying season by spring haying of fall-overseeded annuals. Berseem clover (*Trifolium alexandrinum* L.), crimson clover (*T. incarnatum* L.), annual ryegrass (*Lolium multiflorum* L.), and wheat (*Triticum aestivum* L.) were compared with a nonoverseeded control. Dry matter (DM) yield and N and P uptake were measured in spring and summer hay on a Prentiss sandy loam (coarse-loamy, siliceous, thermic Glossic Fragiudults, Ultisols) with high soil P following 6 yr of swine (*Sus scrofa domesticus*) effluent fertilization. Fall-seeded plots were cut twice for spring hay and three times for summer hay. Spring hay of annual ryegrass (3.8–5.3 Mg ha^{-1} yr^{-1}) yielded more DM than crimson clover (2.6–3.4 Mg ha^{-1} yr^{-1}), wheat (2.5–3.3 Mg ha^{-1} yr^{-1}), and the control (2.8–3.4 Mg ha^{-1} yr^{-1}) every year but did not differ from berseem clover (3.1–4.6 Mg ha^{-1} yr^{-1}) in 2 of 3 yr. Phosphorus uptake in spring hay of annual ryegrass and berseem clover (10–16 kg ha^{-1}) was higher than crimson clover (8–12 kg ha^{-1}), wheat (7–12 kg ha^{-1}), and the control (6–11 kg ha^{-1}). Nitrogen uptake in spring hay was higher in berseem clover (71–128 kg ha^{-1}) than other treatments (43–80 kg ha^{-1}), which did not differ. No differences occurred in summer hay (DM = 3.9–7.6 Mg ha^{-1}, N = 72–191 kg ha^{-1}, P = 13–21 kg ha^{-1}). Overseeding common bermudagrass with berseem clover or annual ryegrass can improve hay yield and P removal.

Bermudagrass is a warm-season perennial, which is widely grown for summer grazing and hay production in the southeastern USA (Burton and Hanna, 1985). It may be harvested from early summer until fall and is often used in manure nutrient management systems (Adeli and Varco, 2001; Adeli et al., 2003; Brink et al., 2003; Burns et al., 1985; King et al., 1985). Many hybrid cultivars respond well to nutrients from swine effluent (Burns et al., 1990; King et al., 1990). Consequently, bermudagrass receives more manure effluent than other forages in the southeastern USA.

Manure application to agricultural lands and crops is often regulated according to soil P levels, known as the P index (Mallarino et al., 2002). Characterizations of cropping systems for P uptake and long-term soil nutrient management are important steps in increasing uptake of soil-available P and reducing P losses in runoff (Rowe and Fairbrother, 2003; Sharpley and Halvorson, 1994). Utilizing this manure resource by replacing commercial fertilizers with manure nutrients for forage production has been the focus of considerable research (Adeli et al., 2002; Burns et al., 1990; Sims and Wolf, 1994).

Recent research comparing hybrid and common bermudagrass has shown the response of common bermudagrass to swine effluent nutrients to be as good as or better than that of some hybrid cultivars (Brink et al., 2003; McLaughlin et al., 2004).

Nutrient uptake is a function of nutrient concentration and plant biomass, both of which may vary due to differences in cultivars, weather, soil properties, and management practices (Adeli et al., 2003; Robinson, 1996; Rowe and Fairbrother, 2003). Brink et al. (2003) found that differences in nutrient concentration produced P uptake (kg ha^{-1}) in common bermudagrass equal to or greater than that of several hybrids, despite lower annual DM production by common bermudagrass. Harvesting of all types of bermudagrass hays is restricted to warm summer months. Improvements in annual forage DM production and nutrient uptake in bermudagrass-based systems may be made by effectively extending the forage production season. Double-cropping warm-season bermudagrass with cool-season annual forages has been used successfully in grazing systems and could be applied to swine manure nutrient management systems in the southeastern USA. Cool-season annual forages seeded into dormant bermudagrass in the fall can provide more winter ground cover and earlier spring growth than bermudagrass alone and have largely unexplored potential in nutrient management hay cropping systems in the region (McLaughlin et al., 2001; Rowe and Fairbrother, 2003).

The objectives of the present study were to determine the effects of overseeding common bermudagrass grown for hay in a swine effluent nutrient management system and to compare DM yield and N and P uptake among overseeding treatments. The goal of the research was to extend and expand the nutrient uptake capacity of the common bermudagrass-based hay system.

MATERIALS AND METHODS

The study was conducted in a hay field on a private hog farm near Pheba in western Clay County, Mississippi, USA (33°59′ N, 88°99′ W). Experimental plots were located on a Prentiss sandy loam (coarse-loamy, siliceous, thermic Glossic Fragiudults, Ultisols) with 2 to 5% slope. The field received anaerobic swine lagoon effluent and produced summer hay from a well-established stand of common bermudagrass. The field

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Abbreviations: DM, dry matter.

Table 1. Background soil test levels at the start of the study.

Depth	Percentage OM†	pH	P	K	Ca	Mg	Zn
cm	%		mg/kg				
		Inside irrigated area					
0–2.5	3.8	7.9	232.0	621.9	1256.0	345.0	2.1
2.5–5	2.5	8.0	128.4	495.9	982.5	174.5	1.1
5–10	1.6	7.9	33.3	300.1	841.1	83.5	0.7
10–20	1.0	7.0	9.9	102.4	724.4	44.3	0.4
		Outside irrigated area					
0–10	1.2	5.5	4.5	42.5	736	40	0.6

† OM, organic matter.

Table 2. Total N and P applied in effluent.

Year	Effluent applied	Nutrients N	P	N/P
	ha cm	kg ha^{-1}		
2000	3.6	258	46	5.6
2001	7.1	533	93	5.8
2002	6.8	513	90	5.7
3-yr total	17.5	1304	229	5.7

was irrigated with effluent from April through October of each year beginning in 1994. Soil test nutrient levels were measured in the plot area of the field in October 1999 at the start of the study (Table 1). These samples were submitted to the Extension Soil Testing Laboratory at Mississippi State University for analysis. The Lancaster method of P extraction was used for these samples (Cox, 2001). Final soil test nutrient levels were determined from soil samples collected in each plot in October 2002. Selected soil chemical characteristics, including P concentration, were determined for each final sample using Mehlich-3 extractant (Mehlich, 1984). Soil NO_3 concentrations were determined using methods described by Mulvaney (1996). Rainfall records in the vicinity of the study were obtained from the National Weather Service for the period of the study (Fig. 1). Rainfall during the first year of the study was below normal, and lagoon levels, which are normally high following winter rains, were relatively low in the spring and summer of 2000; thus, effluent applications were reduced in that year. Timing and amounts of effluent applications were determined by the farm manager. Applications began in April and ended in October. Effluent applications to the plots were collected and measured using meteorological rain gauges placed along the radial axis of the center pivot irrigation field next to each block of the experiment. Volumes of four replicate samples were recorded immediately after each effluent application, combined, and frozen for subsequent nutrient analysis (Brink et al., 2003). Variability among replicate samples collected was about 1 ± 0.25 mm per collection gauge. Total amounts of effluent applied during the study and amounts of plant-available N and P in the effluent are listed in Table 2.

Experimental plots were 2 by 5 m and were separated and surrounded by 1-m alleys and borders. Overseeding treatments consisting of four cool-season annual forages and a nonoverseeded control were arranged in a randomized complete block design replicated four times. Treatments were repeated in the same plots each year. The clovers (22 kg seed ha^{-1}) and ryegrass (34 kg seed ha^{-1}) were seeded using an Almaco drill seeder, and wheat (84 kg seed ha^{-1}) was seeded using a Tye drill. Annuals were drilled in rows 18 cm apart. Plots were prepared for planting by clipping the bermudagrass at a cutting height of 2.5 cm. Seeding was done on 14 Oct. 1999, 12 Oct. 2000, and 10 Oct. 2001. Broadleaf weeds growing in the plot area in fall 1999 were controlled by application of 2,4-DB [4-(2,4-dichlorophenoxy)butanoic acid] herbicide applied at the recommended rate on 9 December using a backpack sprayer. All annuals produced good stands in overseeded plots each year. Plant density in the plots was not recorded, but typically berseem clover produced denser stands than crimson clover, and annual ryegrass produced denser stands than wheat.

Plots were harvested for hay at 4- to 6-wk intervals beginning in April (Fig. 2). Harvesting, preparation, and testing of forage samples were as described for a concurrent study of overseeded hybrid bermudagrass (McLaughlin et al., 2005).

Overseeding treatment effects on DM yield and nutrient uptake of cool-season annual spring hay were tested using summed data from Harvests 1 to 2 (Fig. 2). Treatment effects on DM yield and nutrient uptake of common bermudagrass hay were tested using cumulative data summed from Harvests 3 to 5 (Fig. 2). Cumulative DM yield and uptake were also calculated for sequential harvests within each year. Cumulative

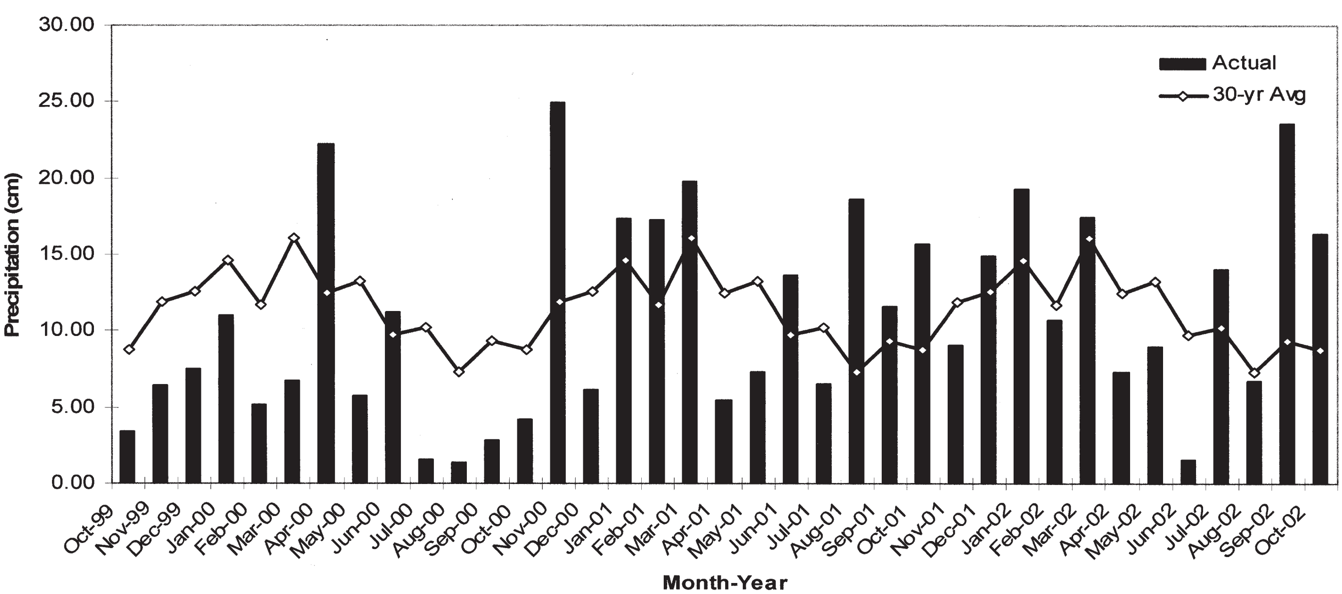

Fig. 1. Actual and 30-yr mean monthly precipitation during the course of the experiment. Data were recorded by the National Weather Service in the vicinity of the experimental plots.

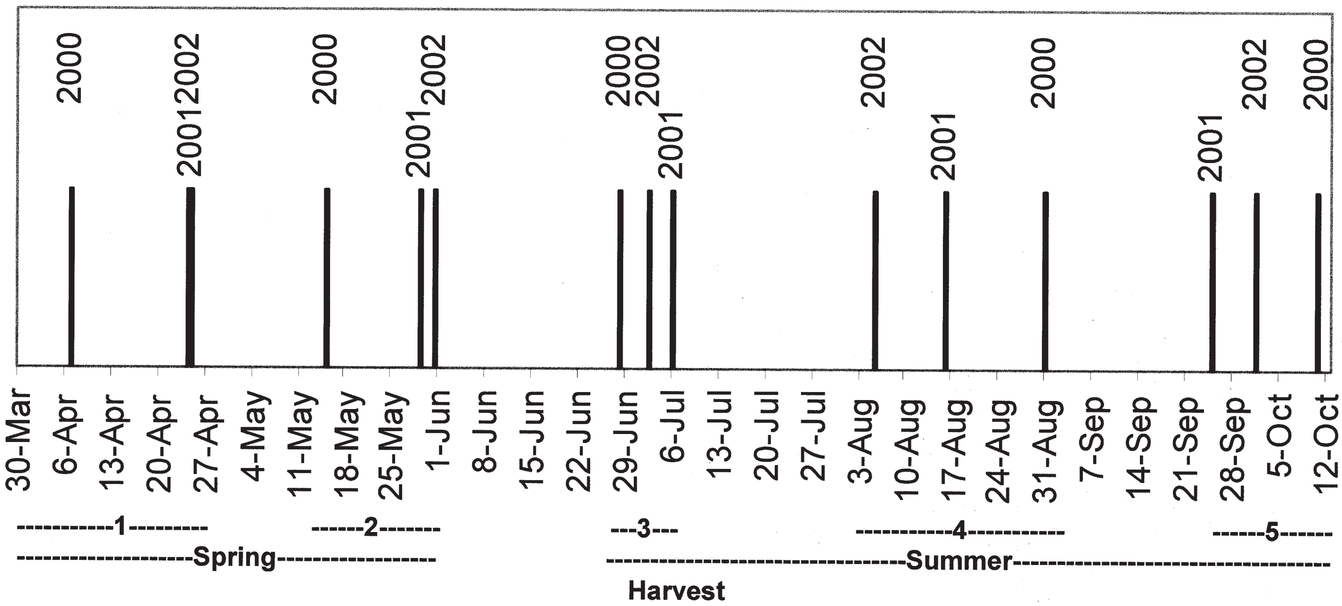

Fig. 2. Dates of five annual harvests of common bermudagrass plots with combinations of 1 to 2 and 3 to 5 used in spring vs. summer comparisons.

DM yield data were analyzed using SAS mixed model and general linear models procedures (Littell et al., 1996; SAS Inst., 1990). Year × harvest ($P < 0.0001$), harvest × treatment ($P < 0.0001$), and year × harvest × treatment ($P < 0.046$) interactions were significant, so treatments were compared by year. Treatment means for DM yield and N and P uptake were compared by Fisher's protected LSD ($P \leq 0.05$).

RESULTS AND DISCUSSION

Dry Matter Yield

Cumulative DM yields were consistently higher in ryegrass treatment plots than in the control treatment in the first and second harvests each year (Fig. 3). Cumulative DM yields in the berseem clover treatment plots were consistently higher than the control in the second harvest (Fig. 3). Berseem and ryegrass treatments started with higher yields in the spring harvests of cool-season annual hays, but by the end of each summer season, differences in cumulative DM yield between treatments were no longer significant. Although treatment differences were not always significant, the nonoverseeded control consistently ranked lowest in DM yield at the end of each growing season (Fig. 3). Cumulative DM yields were lower in all treatments in 2000 than in other years, due to the drought (Fig. 1) and reduced effluent applications (Table 2).

Comparison of overseeding treatments for cumulative DM yields within spring and summer harvests (Fig. 4) showed that DM yields in ryegrass and berseem clover treatments were higher than those in control plots for spring harvests but not for summer harvests. The spring

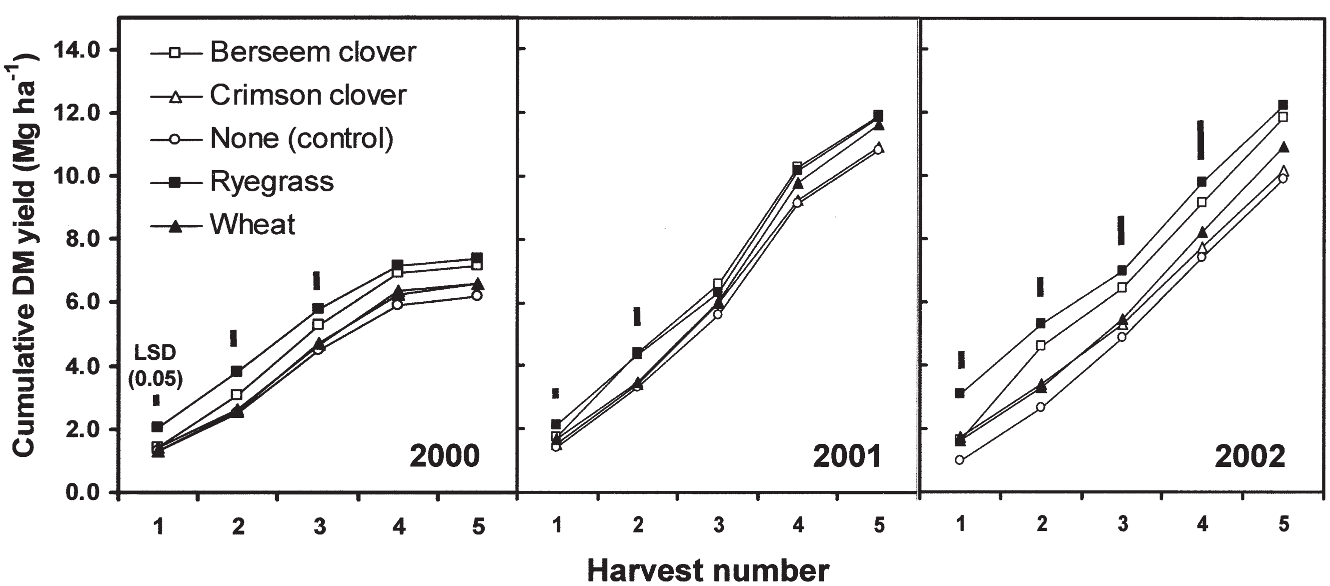

Fig. 3. Cumulative dry matter (DM) yield for each of five winter annual overseeding treatments through five harvests annually in common bermudagrass plots.

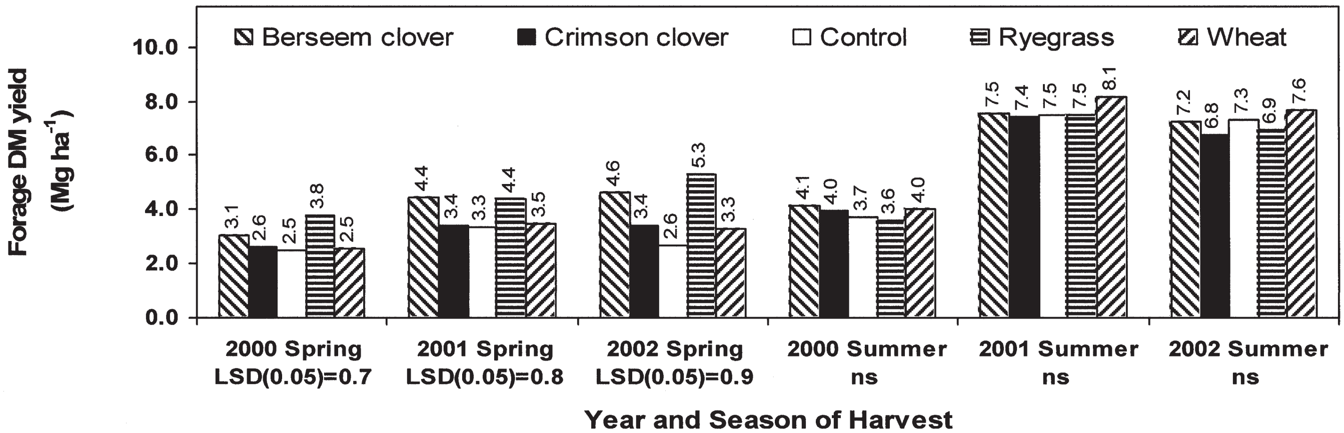

Fig. 4. Cumulative forage dry matter (DM) yields from two spring and three summer harvests in each of 3 yr for common bermudagrass plots following fall overseeding with winter annuals.

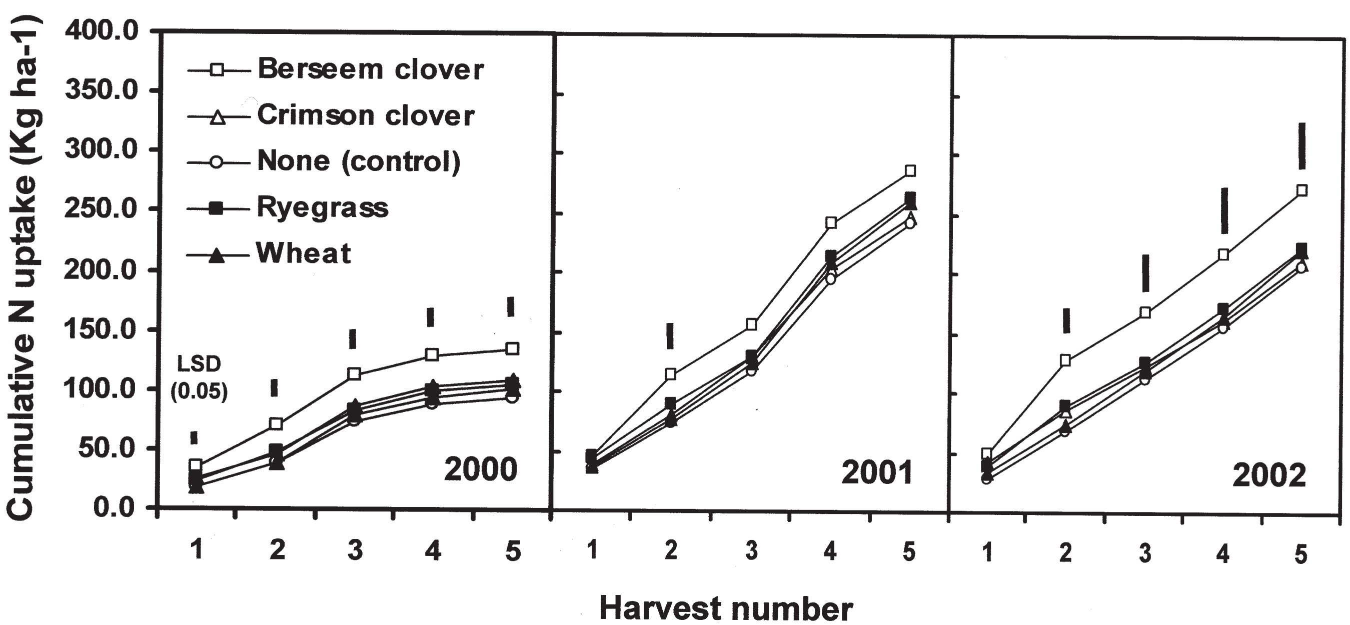

Fig. 5. Cumulative N uptake for each of five winter annual overseeding treatments through five harvests annually in common bermudagrass plots.

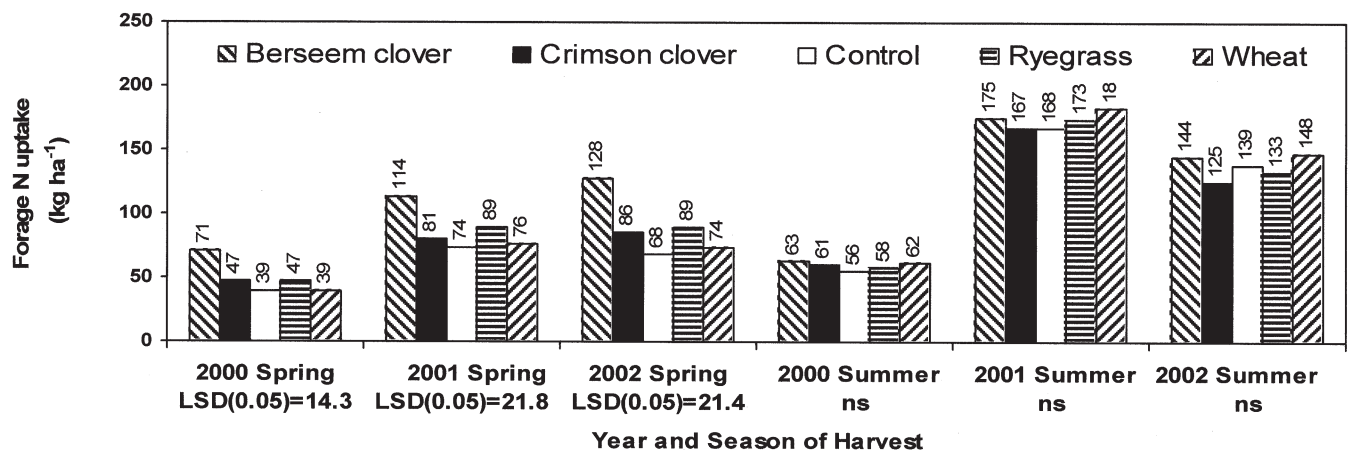

Fig. 6. Cumulative forage N uptake from two spring and three summer harvests in each of 3 yr for common bermudagrass plots following fall overseeding with winter annuals.

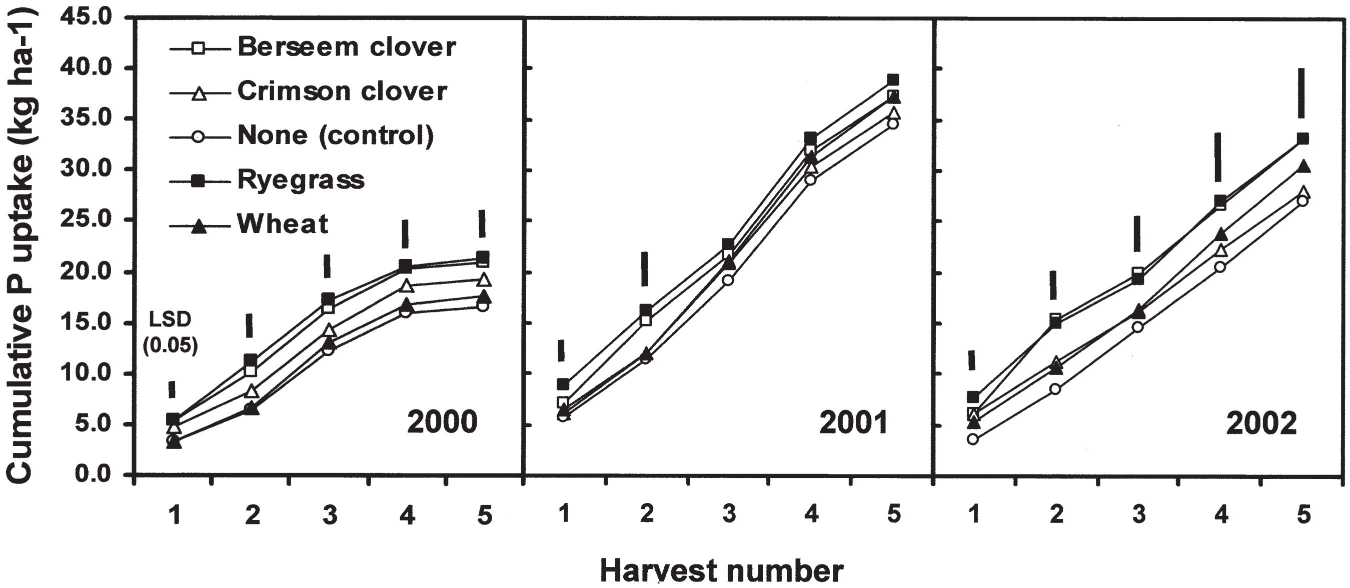

Fig. 7. Cumulative P uptake for each of five winter annual overseeding treatments through five harvests annually in common bermudagrass plots.

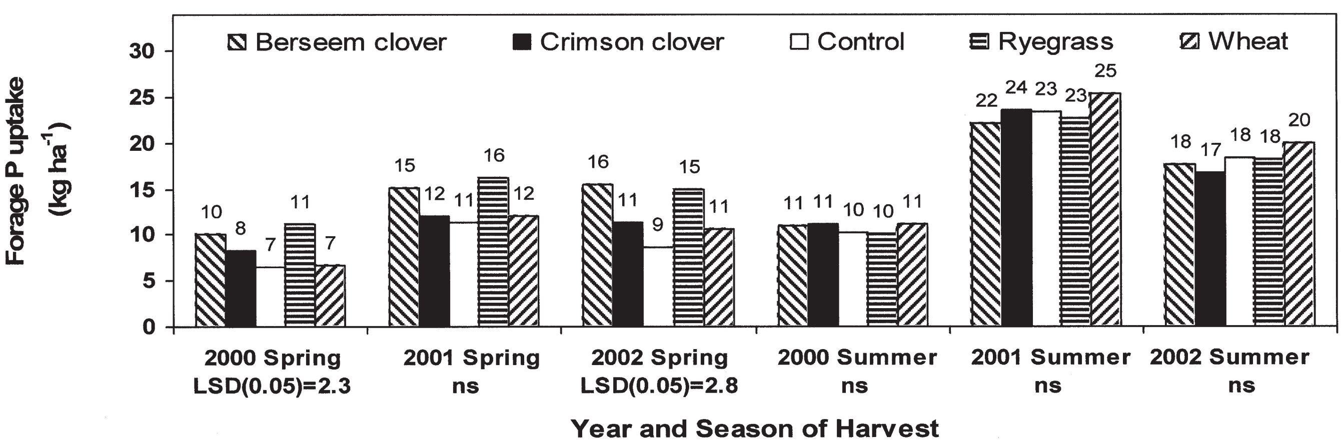

Fig. 8. Cumulative forage P uptake from two spring and three summer harvests in each of 3 yr for common bermudagrass plots following fall overseeding with winter annuals.

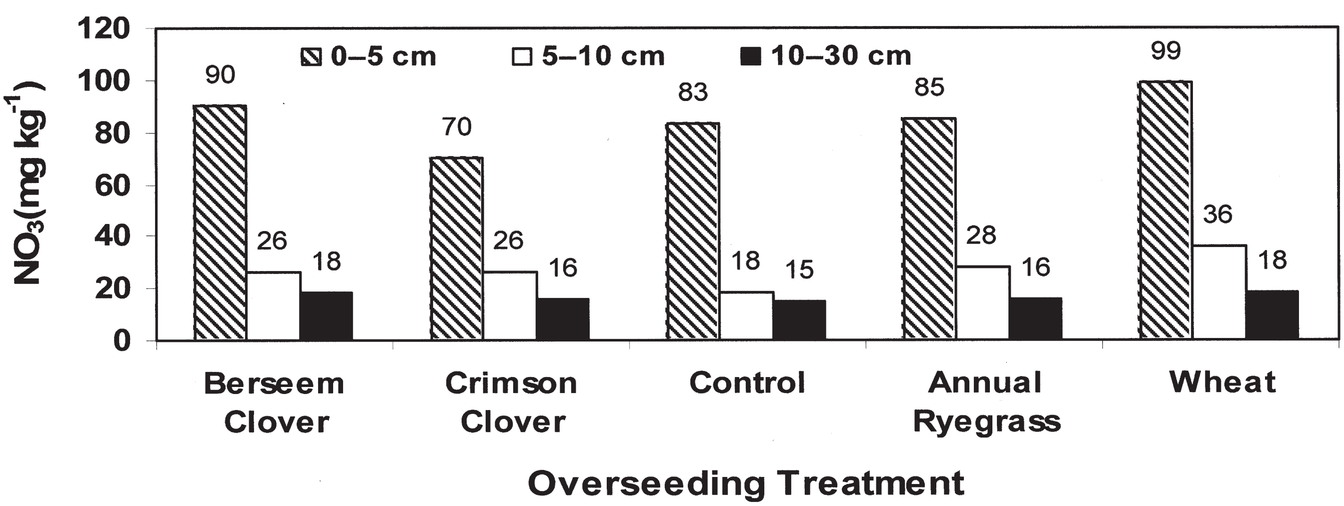

Fig. 9. Soil test NO_3 levels in common bermudagrass plots after the 3-yr overseeding experiment with cool-season annuals. Differences between treatments means within sampling depths were not significant.

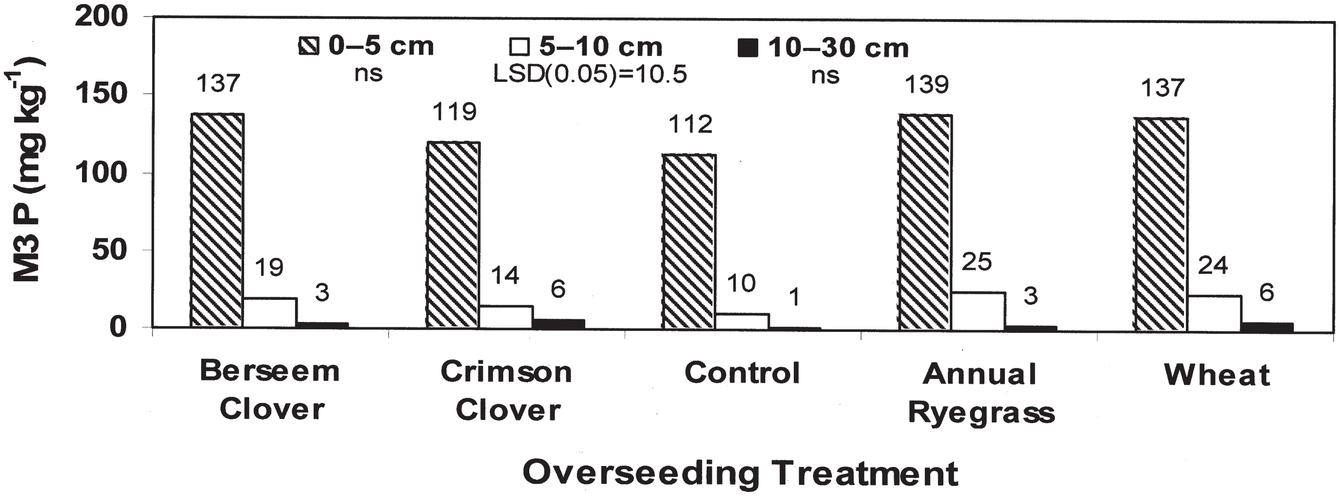

Fig. 10. Mehlich-3 soil test P levels in common bermudagrass plots after the 3 yr of overseeding with cool-season annuals. Differences between treatment means within sampling depths were not significant (ns) except for samples from 5 to 10 cm.

DM yields in the ryegrass treatment were higher than the control in all 3 yr, and spring DM yields in the berseem treatment were higher than the control in 2001 and 2002. The effects of the drought of 1999–2000 were evident across all treatments in reducing DM yields for both spring and summer harvests compared with those of 2001 and 2002 but were more pronounced in the summer DM yields of common bermudagrass (Fig. 4). No treatment effects on DM yield were observed in summer harvests, indicating no residual effects of the cool-season annual species on subsequent growth of common bermudagrass.

Nitrogen and Phosphorus Uptake

Cumulative uptake of N was higher in the berseem clover treatment than in the other treatments in 2000 and 2002 and after two harvests in 2001 (Fig. 5). This trend was evident in later harvests in 2001, but treatment means did not differ significantly (Fig. 5). The N uptakes of the other four treatments were consistently similar in all 3 yr. Removal of N was greater in berseem clover than in the control treatment in spring harvests all 3 yr but not in the summer grass harvests (Fig. 6).

Final cumulative uptake of P was higher in the berseem clover and ryegrass treatments than in the control in 2000 and 2002 but not in 2001 (Fig. 7). These increases in P uptake in the berseem clover and ryegrass treatments were due to the cool-season annual hays harvested in the spring and not to the common bermudagrass hay subsequently harvested in summer (Fig. 8). No treatment effects were observed for P uptake by common bermudagrass in summer harvests.

Residual Soil Nitrate and Mehlich-3 Phosphorus

Soil test NO_3 levels from soil cores collected at the end of the study showed no differences in soil test NO_3 levels between treatments at any of the soil core depths tested (Fig. 9).

Soil test Mehlich-3 P levels from soil cores collected in treatment plots at the end of the study showed no differences between treatments in the 0- to 5- and 10- to 30-cm core samples, but Mehlich-3 P levels were higher in 5- to 10-cm core samples following ryegrass and wheat than after crimson clover and control treatments (Fig. 10). It is likely that the fibrous root systems of the cool-season grasses favored greater redistribution of P at this soil depth than the tap root systems of the clovers. Such P redistribution would follow annual death and decay of the roots and come both from P released by the decaying roots and P carried in surface water percolating down through channels left by the decaying roots. Uptake of P was not determined for roots in the present study; however, data from Pederson et al. (2002) were used to calculate P uptake by roots of annual ryegrass, wheat, berseem clover, and crimson clover. These calculations showed 152, 88, 75, and 56 mg P m^{-2} in roots of ryegrass, wheat, berseem clover, and crimson clover, respectively, representing 7.4, 4.9, 4.5, and 6.4% of the total P uptake in the respective forages in their earlier study. Recognizing differences in root system morphologies and in P partitioning into roots by different forages can contribute to better understanding of how these forages differ in P redistribution in soil, but the more critical factor in selecting forage systems for P management is total P removal in harvested hay.

Soil test P levels at the end of the study (Fig. 9) were nominally much lower than those at the start of the study (Table 1), but direct comparisons were not possible because the Lancaster P extraction method was used to measure initial P levels while the Mehlich-3 method was used to test levels at the end of the study. Results from these two methods may not be reliably converted for direct comparison (Cox, 2001); however, data obtained from the two methods nevertheless demonstrated high soil test P levels during the study. This confirmed that results from these comparisons of hay yields and nutrient uptake by the overseeding treatments were applicable to high P soil.

CONCLUSIONS

Growth of common bermudagrass was not affected by overseeding with any of the cool-season annual forages tested. Overseeding with ryegrass increased total DM hay yields 36 to 56% in spring harvests compared with the nonoverseeded control in all 3 yr of the study, and overseeding with berseem clover increased DM yield 11 to 35% over the control in 2001 and 2002. These increased cumulative annual DM yields were due to spring hay yields since common bermudagrass hay yields in summer harvests did not differ. Overseeding with berseem clover increased total annual N uptake 43 and 31% over the nonoverseeded control in 2000 and 2002, respectively, and showed the same trend in 2001 although differences in 2001 were not significant. The increased N uptake was due to increases in N uptake in spring-harvested berseem clover hay. Overseeding with berseem clover or ryegrass increased total annual P uptake 6 and 22% over the nonoverseeded control in 2000 and 2002, respectively, and increases were attributed to the spring hay harvests. Overseeding did not affect summer P uptake in common bermudagrass, which averaged 11 to 23 kg ha^{-1} yr^{-1}, and soil NO_3 and Mehlich-3 P levels (0–5 cm) at the end of the study did not differ among overseeding treatments. Overseeding common bermudagrass with berseem clover or annual ryegrass can be worthwhile and can provide additional tools for increasing P uptake and hay yield in common bermudagrass hay fields fertilized with swine effluent in the southeastern USA. The success of and benefits from overseeding, however, depend on harvesting spring hay, which also poses the greatest potential difficulty. More frequent rains, higher soil moisture, and cooler temperatures in spring than in summer generally preclude early spring hay harvests in the region and push first harvests into late April or early May. Adoption of alternate harvesting technologies, such as haylage, might overcome this problem and allow earlier spring harvests, which would favor increased yield and nutrient uptake.

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